Freshwater Issues for National Parks of the Northeastern United States

PHASE II: Selection of Water Quality Monitoring Variables for NETN Parks

Submitted to the National Park Service by:

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LIST OF ACRONYMS

ACAD	Acadia National Park
ANC	Acid neutralizing capacity
BMP	Best management practices
BOHA	Boston Harbor Island National Recreation Area
CASTNET	Clean Air Status and Trends Network
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
IBI	Index Biotic Integrity
MABI	Marsh-Billings-Rockefeller National Historical Park
MIMA	Minute Man National Historical Park
MORR	Morristown National Historical Park
MWRA	Massachusetts Water Resources Authority
NADP	National Atmospheric Deposition Project
NAWQA	National Water-Quality Assessment Program
NHP	National Historical Park
NHS	National Historic Site
NOAA	National Oceanic and Atmospheric Agency
NP	National Park
NPS	National Park Service
NRA	National Recreation Area
NETN	Northeast Temperate Network
QA/QC	Quality assurance/quality control

ROVA	Roosevelt-Vanderbilt National Historic Site
SAGA	Saint-Gaudens National Historic Site
SAIR	Saugus Iron Works National Historic Site
SARA	Saratoga National Historical Park
USGS	U.S. Geological Survey
WEFA	Weir Farm National Historic Site

Introduction

The Northeast Temperate Network (NETN) is made up of the following 10 National Parks (NP), National Historical Parks (NHP), National Recreation Areas (NRA), and National Historic Sites (NHS):

1. Acadia NP, Maine (ACAD)
2. Boston Harbor Island NRA, Massachusetts (BOHA)
3. Marsh-Billings-Rockefeller NHP, Vermont (MABI)
4. Minute Man NHP, Massachusetts (MIMA)
5. Morristown NHP, New Jersey (MORR)
6. Roosevelt-Vanderbilt NHS, New York (ROVA)
7. Saint-Gaudens NHS, New Hampshire (SAGA)
8. Saugus Iron Works NHS, Massachusetts (SAIR)
9. Saratoga NHP, New York (SARA)
10. Weir Farm NHS, Connecticut (WEFA)

In all NETN parks, freshwater resources are subjected to natural and anthropogenic impacts and alterations, which, in some cases, have imposed stress on these resources for many years. Current and historic threats facing aquatic ecosystems in National Park Service (NPS) units throughout the northeastern U.S. have led to specific physical, biological, or chemical stressors to the freshwater ecosystems.

The amount of available water-quality and water-quantity data is variable for the NETN parks. Although limited water-quality monitoring has been done in each of the parks, no systematic water-quality and water-quantity data have been collected with adequate quality assurance over a period of record sufficient to characterize baseline conditions and evaluate spatial and temporal changes in freshwater resources throughout a park. The documentation of baseline water-quality and water-quantity conditions is critical to the long-term maintenance of freshwater resources in the parks. Changes in baseline conditions will assist natural resource managers to identify and manage stressors in park freshwater ecosystems.

A project to design freshwater-resources monitoring will be conducted in three phases.

PHASE I: Produce a scoping report for the NETN parks.

PHASE II: Design prototype guidance for monitoring freshwater resources in the NETN parks. This includes prioritizing the list of candidate monitoring variables into a final list of variables (vital signs) that will be measured in all NETN parks.

PHASE III: Conduct feasibility (pilot) testing of recommended freshwater-quality/aquatic-resource vital signs at select NETN parks in order to finalize the freshwater-resource-monitoring design for the network.

This report is a product of Phase II, in which the list of vital signs developed in Phase I, is reviewed and ranked, and specific measures of high-priority vital signs are proposed. The report includes a summary of a workshop in which professionals in the field of freshwater-quality monitoring discussed the potential list of vital signs and made recommendations as to their ecological relevance, management significance and utility, feasibility, and response variability.

The report also includes a comparison of the recommended list of high-priority vital signs and the water-quality monitoring that is currently taking place in the parks. This includes a preliminary evaluation of the availability of protocols, the identification of quality-assurance and quality-control measures, and/or data storage practices.

Summary of the FreshwaterAquatic Session at the Vital Signs Selection Workshop

The objective of the aquatic workgroup was to review and make changes to the preliminary list of freshwater aquatic vital signs. In the initial review, workgroup participants added, removed, renamed, and regrouped vital signs. The second part of the review process was to rank the new list. A summary of appreciable changes to vital signs follows. A list of changes in names or groupings is provided in table 1.

Table 1. Summary of vital signs, rankings, and aquatic workgroup justifications. [H, high; M, medium; L, low; NA, not applicable]

Category	***Original vital sign***	***Workgroup vital sign***	***Justification***	***Initial rank***	***Workgroup rank***
Climate	Basic climate	Climate	Measures such as temperature & precipitation critical to understanding ecological condition of aquatic resources. Provides background explanation for changes or variations in other vital signs. Available from other agencies- we can compile & regionalize.	M	H
Disturbance	Natural disturbance regime	Natural disturbance regime	High ecological relevance. Low management relevance.	L	L
Hydrology/ Geomorphology	Morphology - channel	Stream morphology	Necessary to compile/collect this information in order to better design monitoring program. Could be monitored on a periodic/infrequent basis.	M	H
	Morphometry - lake	Lake morpho-metry	Necessary to compile/collect this information in order to better design monitoring program.	M	H

Category	*Original vital sign*	*Workgroup vital sign*	*Justification*	*Initial rank*	*Workgroup rank*
	Water quantity	Water quantity	Important information, but optional because of cost/feasibility. Lake levels may be feasible, whereas streamflow could be prohibitively expensive. Important to map distribution of springs and seeps.	H	H
	Substrate composition	Substrate composition	Used on an optional/site-specific basis at some parks. Too difficult to apply parkwide at all parks. May be reasonable at smaller parks.	M	M
Abiotic condition	Core water chemistry, Water quality - total dissolved ions, Water quality - total organic carbon	Water chemistry	Essential indicator for any long-term aquatic monitoring program. Critical for interpreting biotic condition & ecological processes. Easily collected--readily available protocols	M	H
Biotic condition	Focal taxa - Fish	Focal taxa- fish	By definition, not an indicator of ecological condition. May be more appropriately covered by other programs.	L	L
	Species composition - fauna	Fish community composition	Fish integrate physical, chemical & biological environment over long term-- esp. in streams	H	H
Biotic Condition (cont.)	Species composition - fauna	Zooplankton community composition in lakes	Indicative of trophic status of lakes- respond to changes in water chemistry, nutrients, and predation by fish and other invertebrates. Has not been applied as widely as fish or macroinverts in streams.	NA	H
	Species composition - flora	Phyto-plankton community composition	Medium priority in lakes, but not as important as other indicators	NA	M
	Species composition - flora	Macrophyte community composition	Medium priority in lakes, but not as important as other indicators	NA	M
	Species composition - flora	Periphyton community composition	Medium priority in streams, but not as important as other indicators	NA	M

Category	***Original vital sign***	***Workgroup vital sign***	***Justification***	***Initial rank***	***Workgroup rank***
	Species of concern	Species of concern	Not necessarily a good indicator of ecological condition.	L	L
	Water quality - algal biomass, Water quality – clarity, Water quality - Lake trophic status, Water quality - nutrient loading	Trophic status	Indicative of stress-- widely understood by land managers and often linked to management actions. Standard protocols can be rapid, cost effective & easily tracked.	H	H
	Water quality-macro-invertebrates	Macro-invertebrate community composition in streams	Macroinvertebrates integrate physical, chemical & biological environment over short term-especially in streams. Numerous protocols available.	M	H
	Water quality-micro-organisms	Water quality – micro-organisms	More a public health concern than indicator of ecological condition.	H	L
Ecological process	Nutrient cycling	Nutrient cycling	Low management relevance inititally. Could be useful to interpret other monitoring variables later in program	M	L
	Phenology	Phenology	Low management relevance inititally. Could be useful to interpret other monitoring variables later in program	M	L
	Trophic dynamics	Trophic dynamics	Low management relevance inititally. Could be useful to interpret other monitoring variables later in program	M	L
Focal park resource	Mandated Species	Mandated Species	By definition, not an indicator of ecological condition. May be more appropriately covered by other programs.	M	L
Landscape context	Landcover, Landscape buffer, Landuse, Park boundary	Landcover/ Landuse	Important as an inventory variable-- may need to update on a periodic basis as needed.	H	H

Category	*Original vital sign*	*Workgroup vital sign*	*Justification*	*Initial rank*	*Workgroup rank*
Management	Land management, Park infrastructure, Trail network	Park management	Minimal ecological relevance if already being tracked/evaluated by park staff.	M	L
	Visitor use	Visitor use	Fish stocking/fish harvesting the primary concern- only at some parks.	M	M
Stressor	Acidic deposition & stress	Atmospheric deposition	High ecological relevance. Best strategy may be to collect this information from other sources because of high cost/complexity	H	H
	Beaver engineering	Hydrologic alteration	Will be tracked with water quantity.	H	L
	Contamin-ation, Heavy metal contamination	Contamin-ation	Important to map sources of contamination and compile this information in a database before the feasibility/necessity of a monitoring program can be assessed. Important at some parks, but expensive.	M	H
	Fertilizer use	Fertilizer use	Will be covered by landcover/landuse	M	L
	Herbicide/ pesticide use	Herbicide/pe sticide use	Will be covered by landcover/landuse	M	L
	Invasive exotic species	Invasive exotic species	Important management concern at all parks. Presence/absence surveys & early intervention critical for health/viability of native species.	H	H
	Roads	Roads	Top management concern, but could be picked up by other vital signs such as landuse & water chemistry. May guide site selection.	H	M
	Septic systems/Wast ewater Discharge	Septic systems/ Wastewater Discharge	Important for understanding trends in water quality. Trophic status may give an indication of the extent of this problem, but worth collecting number of septic systems/discharges explicitly.	M	H
	Shoreline erosion/sea level rise	Shoreline erosion/sea level rise	Not a big concern for freshwater aquatics	H	L

Category	Original vital sign	Workgroup vital sign	Justification	Initial rank	Workgroup rank
Stressor (cont.)	Soil erosion	Soil erosion	Site specific issue- not a widespread concern at most parks	H	L
	UVB	UVB	Low management relevance.	M	L

Review and Ranking of Vital Signs

The vital sign "Core water chemistry" was changed to "Water chemistry" and now includes total dissolved ions, and total organic carbon as mandatory measures in addition to the previous mandatory measures of pH, temperature, dissolved oxygen, and specific conductance. The high priority remained. The vital sign "Water quality-lake trophic status" was changed to the more general "Water quality-trophic status" in order to include streams. The water quality vital signs of "algal biomass," "water clarity," and "nutrient loading" or "nutrients" were incorporated into trophic status. Although lake trophic status was originally ranked as medium, the addition of the other components to this new vital sign caused the workgroup to upgrade the rank to high.

One of the more significant changes the workgroup made was a splitting of "species composition-flora" and "species composition-fauna" into the more specific taxonomic groups: community compositions of fish, macroinvertebrates, and zooplankton for fauna; and phytoplankton, periphyton, and macrophytes for flora. Each community composition vital sign was ranked individually for lakes versus streams, and the highest ranking for each vital sign was chosen for the appropriate target resource. The workgroup ranked fish and macroinvertebrates in streams and zooplankton in lakes as high, while phytoplankton and macrophytes in lakes and periphyton in streams were ranked medium.

"Focal taxa fish," "species of concern," and "mandated species" all remained low priorities. Although the importance of these potential vital signs was recognized, the group felt that by definition, they are not necessarily good indicators of ecological integrity and would perhaps more appropriately be monitored by park specific programs. "Water quality-microorganisms," was recognized as important for human health, but was a low priority in terms of its usefulness to assess ecological integrity.

The vital signs "basic climate" and "acidic deposition and stress" were renamed "climate" and "atmospheric deposition," respectively. The importance of these vital signs was not questioned, but the ability of this program to improve greatly on the information that is already being collected by other networks was questioned. They remained high-priority vital signs with the recognition that the inventory and monitoring program may not be collecting data, but rather compiling this information from other sources.

"Natural disturbance regime," "trophic dynamics," "phenology," and "nutrient cycling" were all considered beyond the scope of the inventory and monitoring program, although some of the measures and components of "trophic dynamics" and "nutrient cycling" were incorporated into "trophic status." There was a recognition that these vital signs may be important to understand and interpret data in the future, but would be ranked as low priority for assessment for the present.

The group felt strongly that a distinction should be made between inventory vital signs and monitoring vital signs. Inventory vital-sign information would be collected or compiled at the start of the monitoring program, could potentially guide the design of the monitoring program, and would be critical for interpreting monitoring data by providing context. Inventory vital signs included “lake morphometry,” “channel morphology,” “landcover/landuse” and “contamination.” “Landcover/landuse” included the original vital signs of “landcover,” “landuse,” “landscape buffer” and “park boundary,” while “contamination” included “heavy metal contamination.” The frequency of collection/compilation of these inventory variables could range from biannually to once every decade, and would be guided by changes in the watershed including operational changes at a park.

“Water quantity” remained a high priority. The workgroup recognized that lake levels would perhaps be easy and relatively inexpensive to measure, whereas continuous stream gaging might be prohibitively expensive. The mapping of springs and seeps in the parks was moved from its own category to now be included in water quantity.

The group did not reach consensus regarding “substrate composition.” Some workgroup members felt it would be more appropriately named “benthic habitat.” This received a rank of medium recognizing that in some parks it may be possible and (or) critical while in other parks it may be not as important and difficult to characterize across the entire park.

The vital sign called “park management” includes “land management,” “park infrastructure,” and “trail network.” This vital sign was ranked low because workgroup participants felt that these features were probably already well monitored by the parks and (or) documented information that was available or could be accessed as necessary. “Visitor use” remained its own vital sign, ranked medium, with the primary concern relating to fish stocking/harvesting. This has a big impact at some parks such as Acadia, and is not currently being monitored. At other parks it is not a significant issue.

There was a fair amount of discussion regarding the category of stressors and how they should fit into a monitoring program of ecological integrity. The conclusions of the workgroup were that “invasive exotic species” and “septic/waste water discharge” were ranked high, “roads” was ranked medium, and the rest were ranked low. The group felt that “fertilizer use” and “herbicide/pesticide” use would be captured in “landcover/landuse”; “soil erosion” was not a serious networkwide issue, but could become important on a case-by-case basis; “hydrologic alterations” (now including “beaver engineering”) would be captured by “water quantity”; “UVB” was beyond the scope of this program; and “shoreline erosion/sea-level rise” was more of an intertidal issue than one of freshwater aquatics.

Justifications, Measures, and Concerns for High Priority Vital Signs

The vital signs presented below are all high-priority vital signs as assessed by the aquatic workgroup. These vital signs address the ecological integrity of the parks and were selected to address the physical, chemical, and biological aspects of the ecosystem. In most cases, the workgroup recommended at least one mandatory measure; in several cases, they recommended multiple mandatory measures and additional optional measures (table 2). The workgroup also discussed and concluded that vital signs may be high priority for specific targets (lakes, streams, or springs/seeps) or may be high priority for all targets. Ground water is only considered as a target where specifically addressed.

Table 2. Mandatory and optional measures for high-priority vital signs recommended by the aquatic workgroup.

Category	**Workgroup vital sign**	**Mandatory measures**	**Optional measures**
Climate	Climate	Air temperature, precipitation by type	Relative humidity, total solar radiation, wind speed, wind direction, snow water equivalent, snow depth
Hydrology/ Geomorphology	Water quantity	None	Ground-water inputs, ground-water levels, lake water levels, spring/seep volume, streamflow
	Stream morphology	Gradient, drainage area, stream order	Run/riffle/pool survey, stream sinuousity, bankful lcross-sectional geometry
	Lake morphometry	Surface area, drainage area, elevation, lake type/origin, maximum and mean depth, bathymetry	Flushing rate
Abiotic condition	Water chemistry	Specific conductance, percent DO saturation, temperature, pH, color, turbidity	Iron, cations, anions, alkalinity/ANC, aluminum, dissolved organic carbon
Biotic condition	Fish community composition	Species abundance, species richness	None
	Zooplankton community composition	Species abundance, species richness	None

Category	Workgroup vital sign	Mandatory measures	Optional measures
	Water quality -- trophic status	Algal biomass, measures of water clarity such as secchi disk, and total and dissolved phosphorus	Macrophyte distribution, diel oxygen curves, periphyton abundance, and dissolved oxygen profiles
	Macroinvertebrate community composition	Species abundance, species richness	None
Landscape context	Land cover/ land use	Land cover/ecological system map	Buffer width, buffer vegetation, percent impervious surface in buffer or watershed, percent canopy shading for streams, patch connectivity, patch fragmentation, patch size distribution
Stressor	Atmospheric deposition	None	Inorganic toxics, dry deposition, mercury, wet deposition
	Contamination	None	Toxic boat paint use and concentrations in water, sediment contamination, MTBE/chloroforms/ trichloroethylene in water, contaminant spills, air toxic concentrations, bioaccumulation in indicator species
	Invasive exotic species	Presence/absence	Relative abundance
	Septic systems/ wastewater discharge	Track number of septic systems in the park	Track nearby septic permits and the location, quantity, and quality of wastewater discharges

Climate

Climate data provide background explanations for changes or variation in other vital signs. Measures of climate such as precipitation and temperature are critical to understanding the ecological condition of aquatic resources and biota (Hynes, 1975; Poff, 1997). Climate data are available so the parks probably will not have to collect them, but rather compile these data from other sources such as the National Oceanic and Atmospheric Administration (monthly reports) or the National Climatic Data Center (Sorenson and others, 1999). The short-term response variability for climate is clear; however the long-term response variability of changing climate is still under investigation.

Mandatory measures include air temperature and precipitation. Optional measures to compile include relative humidity, total solar radiation, wind speed, wind direction, snow water equivalent, and snow depth . Project managers would need to account for spatial variability to extrapolate regional information to parks.

Stream geomorphology

Baseline stream geomorphology will be important to collect and (or) compile from other sources because it is a major physical component of aquatic ecosystems. This information falls into the category of inventory because it will involve infrequent/periodic measurements rather than annual sampling. Channel geomorphologic units change due to both natural and anthropogenic factors (Leopold, 1994). Bankfull discharge, which has a recurrence interval from 1.5 to 2 years, also has been called the "channel forming discharge" and/or effective flow (Andrews, 1980; Leopold, 1994). Overbank flow, or floods, occur at less frequent intervals and can affect riparian zones and land use as well as have significant effects on erosion, bed-load transport, sediment accretion and deposition in the channel, and modification of geomorphic structure of the channel (Leopold and others, 1964; Hill and others, 1991). Anthropogenic developments in the basin can alter the recharge and runoff to the stream and affect runoff by increasing the amount of peak runoff and reducing the duration of runoff.

Mandatory measures include stream order, drainage area, and gradient. In most cases, this will involve compiling available variables in a database. Optional measures could include run/riffle/pool geometry, bankfull cross-sectional geometry, and stream sinuosity from aerial photos or topographic maps. Delineation and measurement of channel geomorphologic units can be accomplished with existing protocols from the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) program or the U.S. Environmental Protection Agency's (USEPA) Environmental Monitoring and Assessment Program (EMAP)(Fitzpatrick and others, 1998; Lazorchak and others, 1998). Representative reaches (20 times the mean channel width from NAWQA or 40 times the mean channel width from EMAP) can be assessed by two people in 2 to 3 hours.

Optional more frequent measurements would include surveys of channel geomorphologic units to quantify habitat types for aquatic biota. Each geomorphologic channel unit provides unique combinations of depth, velocity, and substrate composition. Substrate composition was its own vital sign and is discussed below.

Lake morphometry

Morphometric mapping of lakes provides baseline data for future reference, and may be available from existing sources. Mapping that includes substrate types and extent of macrophyte growth could be used to interpret macrophyte growth patterns, which respond to changes in light penetration, substrates, nutrients, and water depth (Goldstein, 2000).

Mandatory measures include surface area, drainage area, elevation, lake type/origin, maximum and mean depth, and bathymetry. An optional measure would be flushing rate. Lake morphometry can be easily mapped with depth finders (fish finders) and GPS. This baseline information will be compiled initially and could guide monitoring site selection.

Water quantity

Information about water quantity is necessary to interpret other vital signs such as eutrophication, sediment processes, or contaminants because stream discharge is used to calculate annual loads and annual watershed yields. Furthermore, water quantity determines the physical extent and volume of aquatic habitat at the parks. Numerous factors affect water quantity including precipitation, evapotranspiration, water withdrawals, and ground-water recharge.

All measures are optional including ground-water inputs, ground-water levels, lake water levels, spring/seep volume, and streamflow, but measures such as lake water levels are considerably more easily obtained than streamflow, and thus are highly recommended. Existing stream gages with long historical records may be used to extend and interpret incidental measurements and (or) stage gages within parks if a relationship between the two sites is established. Although only two NETN parks have streamflow gages within or adjacent to park boundaries, the closest long-term streamflow gages have been identified in all cases.

Springs and seeps create unique aquatic resources. They are an integral component of ground-water-fed streams and can be critical for understanding the thermal regime and biodiversity of aquatic habitats because they indicate the quantity and quality of water in surficial aquifers as well as the interaction of surface and ground water. Furthermore, they are a good indicator of ecological integrity because they can indicate which contaminants that have been applied in the watershed are reaching surficial ground water and subsequently other aquatic resources (e.g., Cowdery, 1997).

Baseline inventory data should include the location and possibly the seasonality of springs and seeps in the park. Frequent monitoring water quality and quantity of springs and seeps may be beyond the scope of this program, but springs and seeps should be considered as a target for water quantity and water quality on a site specific basis. The relative importance of this information will depend on the size of the park/drainage basin. At smaller parks, the locations may be known; at the larger parks, aerial photography with thermal mapping can be used to locate springs and seeps after/during snowmelt. The size of the springs and seeps will change with climatic conditions and groundwater withdrawals. Water quality will depend on surrounding geology and land use in the watershed.

Water chemistry

Water chemistry directly addresses one of the inventory and monitoring objectives: to detect changes in the status of physical, chemical, or biological attributes or vital signs of the ecosystem. It is an essential indicator to any long-term aquatic monitoring program (Gilliom and others, 1995). It is widely applicable and is critical for interpreting the biotic condition and ecological processes of a resource. Water chemistry affects the bioavailability of contaminants and the metabolism of aquatic species. For example, ionic conditions affect osmo-regulation (Hoar and Randall 1969) and contaminant uptake (Sinley and others, 1974; Luoma, 1989; Spry and Weiner, 1991); dissolved oxygen and temperature affect metabolic rate (Hoar and Randall, 1969). Successful reproduction requires the appropriate chemical conditions for fertilization and development of eggs and larvae (Holtze and Hutchinson, 1989).

Water-quality parameters are sufficiently well known that abnormal conditions and trends can be recognized or determined statistically. Mandatory measures include specific conductance, percent DO saturation, temperature, pH, color, turbidity. Targets include lakes, streams, springs and seeps unless specified. Ground-water chemistry could be considered where monitoring wells are in place.

Optional measures include iron, cations, anions, alkalinity/ANC, aluminum, dissolved organic carbon. Protocols for collection of water samples and standard methods of chemical analysis are widely available (e.g., Shelton 1994). Most of the mandatory water-chemistry measures can be obtained in the field or with relatively inexpensive laboratory analyses. Optional measures will vary depending on the needs of individual parks.

Fish community composition in streams

Richness and composition of fish species is a highly relevant and applicable vital sign because fish communities integrate their physical, chemical, and biological environment through time (Tonn and others, 1983; Gurtz, 1993). Species richness and composition in small streams can be obtained easily with the proper equipment (electro-fishing or small seine) (Meador and others, 1993; Moulton and others, 2002a). An alternative, non-evasive method is direct observation and counts by divers with mask and snorkel (Goldstein, 1978). On average, a site can be sampled in about 2 hours. The size of the stream dictates the number of individuals needed, which will range from two to five (Moulton and others, 2002a). Although a representative sample of a fish community can be obtained from small- to moderate-sized streams, such a sample is not readily obtainable from larger rivers (Moulton and others, 2002a). Fish species composition can be evaluated with multimetric indices of biological integrity such as an index of biotic integrity (IBI) or by examination of species traits (Karr and others, 1986) (Goldstein and Meador, in press). These indices evaluate the quality of the resource by rating the ecological structure and functional composition of the community. Although a reference site normally is used for comparison, the initial sample for the monitoring program will constitute the baseline condition for comparison. Certain metrics can be diagnostic of specific environmental changes (Karr and others, 1986).

Mandatory measures include relative abundance and species richness in a representative sample, i.e., the numbers and identity of all species collected. Fish community composition in streams was ranked high priority wheareas fish community composition in lakes was ranked medium priority.

Zooplankton community composition in lakes

Zooplankton community composition and abundance is indicative of the trophic status of the lakes, reflects primary and secondary production (Porter, 1977), and also implies year class strength of most lotic fish species because early fish life history stages feed primarily on zooplankton. Therefore, community composition and abundance of the zooplankton not only reflect the abundance and composition of the phytoplankton, but also provide a basis for predicting certain aspects of the fish community and fishery. If the timing of zooplankton blooms of the larger sized taxa is concurrent with the hatching of salmonid and centrarchid eggs, then zooplankton provide an abundant food source for these early fish life history stages (Goldstein and Simon, 1998); this implies greater survival, year class strength, and recruitment to the fishery. Like other biotic communities, zooplankton respond to changes in water chemistry, nutrients, and predation by fish and other invertebrates. Changes in zooplankton taxa composition and abundance in lakes has not been applied as an environmental indicator to the same degree as fish or invertebrates in streams.

The mandatory measures of zooplankton species richness and abundance are collected by either horizontal or vertical tows with a plankton net. Abundance (density) is based on the volume of water filtered. Identification and subsampling require special training. Zooplankton collection in lakes was ranked high priority whereas zooplankton collection in streams was ranked low priority.

Trophic status

Eutrophication causes degradation of park aquatic resources. Nutrient inputs cause nuisance algal blooms, unwanted macrophyte growth, odors, and even fish kills (Clady, 1977; Porcella, 1978; Porter and others, 1993). As land use changes from forest to agriculture or urban, the potential sources of nutrients increase. Trophic status is indicative of nutrient stress (Wetzel, 1983). It is widely understood by resource managers that when status levels change, management actions such as application of best management practices (BMPs) may be necessary to reduce inputs. Sufficient information exists in the literature to quantify the trophic status of park lakes based on the measures listed below (Carlson, 1977).

Mandatory measures include algal biomass, measures of water clarity such as secchi disk, and total and dissolved phosphorus. Optional measures include macrophyte distribution, diel oxygen curves, periphyton abundance, and dissolved oxygen profiles. Many of these measures are seasonal. Standard protocols (e.g., Sorenson and others, 1999) can be rapid, cost effective, and easily tracked over time. Secchi disc readings, plankton tows for algal biomass (density) or chlorophyll a, and water samples for nitrogen and phosphorus can all be collected in a short period of time.

Macroinvertebrate community composition in streams

Invertebrate community taxa richness and composition is a highly relevant vital sign in streams because macroinvertebrates integrate their physical, chemical, and biological environment like fish, however, they do so in a shorter temporal period than fish (most invertebrate life cycles are accomplished in a single year compared to multiple years for fish). Therefore invertebrates may provide a "first response" vital sign. The integration is manifest in the taxa richness and composition. Macroinvertebrate community composition has been used to evaluate water quality and aquatic resources (Hilsenhof, 1987; Lenat, 1993). Collection of invertebrate samples is relatively easy. Numerous protocols exist (Lazorchak and others, 1998; Moulton and others, 2002a). For direct collections from natural stream substrates, two people can collect a sample in about an hour using standard equipment, nets with a 595/600-micron mesh (USEPA uses this mesh size for EMAP (Lazorchak and others, 1998). For indirect collections of artificial substrates or natural substrates placed in the stream for colonization, the collection time is less, but an initial site visit is necessary to insert the sampler. The analysis, counting and identification, is not a trivial matter and can take up to 1 day per sample. The identification of invertebrate taxa requires specialized training or a specialty laboratory (Moulton and others, 2002b). Several invertebrate multimetric environmental indices are available for invertebrate data. The USGS has an Invertebrate Data Analysis System that contains more than 130 metrics available for use (Cuffney, 2003).

Mandatory measures include invertebrate taxa richness (measured to the lowest practicable taxa) and taxa abundance from a randomly selected subsample of 100 or 300 individuals from direct collections, but fewer individuals from indirect collections. Taxa abundance is the proportion of each taxa in the subsample. Macroinvertebrate collection in streams was ranked high priority whereas macroinvertebrate collection in lakes was ranked low priority.

Land use/land cover

This land use/land cover vital sign includes “landcover,” “landscape buffer,” “land use,” and “park boundary.” At a watershed level, land use and land cover affect the quality of aquatic environments (Stauffer and others, 2000; Meador and Goldstein, 2003). An initial inventory of land use and land cover will provide context for the observed ecological conditions. If changes occur in this condition, they can be interpreted in the context of land use or land cover at the watershed scale. Aquatic ecosystems respond to changes in landuse, and this response has been documented in urban, agricultural, and forested environmental settings (Meador and Goldstein, 2003).

This is a high-priority vital sign, but the measures can be collected or compiled as part of an initial inventory and updated only as changes in the watershed become apparent. Most measures are optional depending on the park and need to reflect the varying scales and specific requirements of the parks. The only mandatory measure is a landcover/ecological system map. For most parks, these data already exist, are straight forward to interpret, and will help in site selection/prioritization.

Optional measures include buffer width, buffer vegetation, percent impervious surface in buffer or watershed, percent canopy shading for streams, patch connectivity, patch fragmentation, patch size distribution. The park boundary already exists for all parks, and can be updated as necessary.

Atmospheric deposition

Atmospheric deposition includes acid rain, inorganic compounds, and mercury. This vital sign was modified to include all atmospheric deposition (as opposed to just acidic deposition), and now includes only the deposition, rather than the response/stress to the aquatic resource. Measures of atmospheric deposition are critical for understanding water chemistry and stress (Likens and Bormann, 1974). Swain and others (1992) estimated that 90 percent of the mercury entering remote lakes in Voyageurs National Park (Minnesota) is derived from atmospheric deposition. However, these measures are expensive and may be covered sufficiently by other programs. Deposition at coarse resolutions is already measured as part of National Atmospheric Deposition Project (NADP) and the Clean Air Status and Trends Network (CASTNET). Information about deposition should drive site selection for measurements of water chemistry.

Optional measures include inorganic compounds, dry deposition, mercury, wet deposition. Although mercury deposition is an issue throughout the Northeast, other types of atmospheric deposition may be an issue primarily in ACAD and along the Appalachian Trail.

Contamination

All members of the workgroup agreed that contamination (including heavy metal contamination) is ecologically relevant. The accumulation of trace elements and organic compounds in aquatic organisms can cause physiological problems and even death of aquatic organisms. Accumulated contaminants move upward through the food chain.

Initially there is a need for a better assessment of existing data to determine the sources and pathways of contamination. This vital sign may need to be added as a continuous monitoring variable at some parks after the initial inventory and assessment is complete. Some contaminants such as metals may be occurring at high levels "naturally." Responses may be difficult to interpret without long-term data.

All measures are optional and site specific, and include measures of toxic boat paint use and concentrations in water, sediment contamination, MTBE/chloroforms/ trichloroethylene in water, contaminant spills, air toxic concentrations, bioaccumulation in indicator species. Initially it is recommended that an inventory of contaminant sources and historical sites of contamination be compiled in a database if this is not already done. This vital sign would, however, require very expensive laboratory analyses, and may be beyond the scope of this program financially. Composite sampling may help to keep costs down (Correll, 2001).

Invasive exotic species

The presence and extent of invasive exotic species is a critical management concern at all parks in the network. Parks would benefit from quick identification and removal of new invasive species, and monitoring and removal of already established invasive exotic species. Catastrophic consequences to native species, including loss of biodiversity and replacement of native flora and fauna, can result if this vital sign is not addressed.

Routine surveys for the presence/absence of particular invasive species are mandatory at all parks. Lists of non-native species with the potential to invade individual parks already exist in most states. These lists will identify the types of habitats to examine for invasive species. The relative abundance of established invasive species is optional.

Septic systems/wastewater discharge

It is important to collect the number of septic systems/wastewater discharges explicitly to understand trends in water quality related to measures of trophic status. Parks may not be able to affect change in nutrient inputs from wastewater sources outside the park, but this information still helps to interpret trends in water quality.

Tracking the number of septic systems in the park is mandatory and is information that is readily available. Tracking nearby septic permits and the location, quantity, and quality of wastewater discharges are optional measures.

Justifications, measures and concerns for medium-priority vital signs

Although the workgroup is not recommending the following vital signs for immediate inclusion in a monitoring program, information regarding the vital signs is included below because either a minority of workgroup members felt that they should be high-priority vital signs, or there was a general consensus that these medium-priority vital signs should have their priority reassessed as potential high-priority vital signs further into the program as additional funding and (or) partnering with other agencies becomes available. Potential measures are included in some cases.

Phytoplankton community composition

Species richness and species abundance are optional measures. This vital sign was ranked medium priority for lakes and ranked low priority for streams. Phytoplankton respond to the physical and chemical conditions present at the time of collection; they reflect the water quality of the water mass they occupy (Clesceri and others, 1989; Porter and others, 1993).

Periphyton community composition

Species richness and species abundance are optional measures. Periphyton abundance (either cell volume or ash free dry mass) and chlorophyll a in streams can be a useful vital sign for nutrient enrichment, whereas species composition and abundance can be used in an Index of Biotic Integrity (Hill and others, 2000). This vital sign was ranked medium priority for streams and ranked low priority for lakes.

Macrophyte community composition

Species richness and species abundance are optional measures. Inherent in this vital sign are invasive aquatic plant species and a measure of lake eutrophication. Therefore, this sign was considered redundant. This vital sign was ranked medium priority for lakes and ranked low priority for streams.

Substrate composition

This vital sign is an important indicator of aquatic habitat (Stauffer and Goldstein, 1997; Goldstein and others, 2002), but may be reflected in invertebrate taxa composition and abundance. Sedimentation can be a major issue, so a rapid measure of embeddedness could be used. Questions remain as to the frequency of monitoring because changes in substrate composition are related to the frequency of high-flow events (Andrews, 1980; Leopold, 1994). Detailed particle-size analysis is expensive, but visual evaluation techniques and indices could be applied.

Visitor use

Stocking/fishing issues are significant management issues in some parks, but not in others. The workgroup recommended that this be a park-specific vital sign to be monitored as needed. Parks generally do not know amounts of fish being harvested and (or) stocked where these activities are taking place.

Optional measures that the workgroup identified as higher priority include the number of fishing/shellfishing permits, and information regarding stocking (species stocked and location). Lower priority measures include the number of visitors by location and activity and the number of boats.

Roads

Roads were identified as a top management concern in most NETN parks. This vital sign was downgraded to medium because the aquatic workgroup felt that information surrounding roads as stressors could be picked up by other vital signs such as water chemistry, landcover/landuse, and contamination. Site selection/sampling design should, in some cases, be driven by road locations. Specific road-runoff studies are complex/expensive and may be beyond the scope of this monitoring program.

Optional measures include road network information, types of roads, measurements of quantity and quality of road runoff, amounts and types of de-icing chemicals applied, and the presence/quality of nonpoint-source pollution control measures in place.

Conclusions

The workgroup was successful at meeting the objectives of reviewing and ranking the list of potential vital signs and providing initial justifications and measures for all of the vital signs ranked high and for most of the vital signs ranked medium. The goal of including vital signs for each of the three major components of ecosystems (physical, chemical, and biological) was accomplished and the list of high-priority vital signs is well balanced among the three components. Many potential vital signs were consolidated into other vital signs during the process, but in retrospect, it was useful to have all these potential vital signs considered independently. The workgroup found it easier to consider individual vital signs and then group them rather than to separate vital signs with multiple components. All participants provided valuable input.

Current Aquatic Monitoring Programs at NETN Parks

Five parks currently have water-quality and (or) water-quantity monitoring programs. The parks are ACAD, MORR, ROVA, SAGA, and SAIR. BOHA benefits from a monitoring program conducted by the Massachusetts Water Resources Authority (MWRA). The monitoring programs are summarized in the Phase I scoping report. The period of data collection varies; some monitoring programs were initiated as early as the 1970s and some as recently as 1998. The parks that do have monitoring programs primarily include the measures included in the high-priority vital sign water chemistry selected for the NETN monitoring program. Data collected as a part of this program will provide historical comparisons and context for the data collected by the vital-signs program. In some cases, the NETN monitoring program will build on the program currently in place, especially where measures, sampling locations, and(or) sampling protocols are similar across programs. In other cases, however, because the monitoring programs at some of the parks are focused on specific aquatic resources or have different objectives than the vital-signs program, compatibility with the vital-signs program will vary. The remaining five parks (MABI, MIMA, SARA, WEFA, BOHA) have no known current freshwater-quality monitoring at present (2004) and will not be included in this part of the report.

Current Aquatic Monitoring Programs at NETN Parks Compared to High-Priority Vital Signs

The purpose of this section of the report is to determine the compatibility between data currently being collected (including protocols, quality assurance/quality control, and data-storage practices) and the measures associated with the high-priority vital signs selected for the NETN vital-signs monitoring program.

Direct comparisons or incorporation of the data from previous monitoring programs may be problematic for the following reasons. First, methods of analysis may have changed. For example, biological monitoring of stream macroinvertebrate communities has been conducted at four of the five parks, but the protocols or analyses are not consistent across the parks. For chemical analyses, there are different analyses used for certain constituents (e.g., pH) and so the results are not always comparable. Additionally, as chemical analytical methods advance and become more sensitive, detection limits decrease and accuracy and precision increase. As changes in methodology progress, comparability decreases. For those parameters that are consistent with the high-priority vital signs, the number of samples or the frequency of sampling may not be the same. This introduces differences in estimates of variability (standard deviations and coefficients of variation) and affects measures of central tendency such as the mean or median values. At many of the parks, data from the vital signs such as climate and water quantity, which are important for interpreting water quality data, are intermittent or unavailable. Without this contextual information, including information about vital signs such as channel morphology or lake morphometry, historical trends in water quality will be difficult to interpret. Concentrations of chemical components change with dilution, and thus depend on water quantity. Standardization of concentration data by using water quantity data to calculate annual loads and yields can not be accomplished without water-quantity data, and so year-to-year comparisons become difficult.

A matrix shows where suggested measures and current measures intersect (table 3). The high-priority vital signs, and their mandatory and optional measures are listed down the vertical axis and the parks are listed along the top horizontal axis. In the corresponding box under each park are the components of the current monitoring programs.

Climate

None of the parks are collecting climate data. Meteorological measures such as precipitation, temperature, snowfall, snowpack conditions, and wind direction and speed are often available regionally from NOAA, National Weather Service, and the NADP. In some cases, meteorological stations run by these agencies are within or very close to park boundaries.

Stream gemorphology

Only ACAD and MORR are regularly collecting stream geomorphology data. The Rapid Bioassessment protocol conducted at MORR does not, however, include many of the mandatory measures identified for this vital sign. The ACAD program includes many of the mandatory and optional measures. SAIR has limited stream morphology data at the USGS gage.

Lake morphometry

Several parks have had bathymetric surveys done at lakes within the parks. Most parks have estimates of surface area and mean depth of the lakes.

Water quantity

All the parks have access to local USGS stream-gaging data as part of their monitoring program. ACAD has 2 continuous-record streamflow gages within the park, and SAIR has a continuous-record streamflow gage just upstream from its northern boundary. Incidental streamflow measurements are collected at SAGA as part of the monitoring program. A USGS ground-water program at ACAD monitors water levels. None of the parks, except for SAIR, have mapped or consistently measured discharge at springs or seeps.

Water chemistry

All the parks have some type of water chemistry monitoring program. Many of the mandatory high-priority vital signs are collected as part of these programs, e.g., water temperature, pH, dissolved oxygen, and conductivity. Differences then become park specific. Mandatory measures of NETN high-priority vital signs that are currently being measured by park personnel could be incorporated into the NETN monitoring program. The only park where this might pose some difficulty is at SAIR, where water chemistry (except for temperature and specific conductance) is sampled by volunteers.

Table 3. Comparison of current park aquatic monitoring program components with high-priority vital signs.

[Empty boxes indicate no program components for the vital sign at a specific park; USGS, U.S. Geological Survey; NADP, National Atmospheric Deposition Program; NOAA, National Oceanic and Atmospheric Agency; NWS, National Weather Service; NPS, National Park Service; DEP, Department of Environmental Protection].

Vital Sign	Proposed measures	Measures currently collected					
		Acadia National Park	Boston Harbor Island National Recreation Area	Morristown National Historical Park	Roosevelt-Vanderilt National Historic Site	Saint-Gaudens National Historic Site	Saugus Iron Works National Historic Site
Climate	Optional: Air temperature and precipitation Wind speed and direction, precipitation by type, snow depth, snow water equivalent, relative humidity, and solar radiation.	NADP collects precipitation and air temperature data. NOAA and NWS collect precipitation, temperature, snowfall, snowpack conditions, wind direction and speed data.					USGS collects precipitation, air temperature, wind speed and direction data just upstream from park (station does not conform to National Weather Service standards).
Stream geomorphology	Mandatory: Stream order, drainage area, gradient Optional: Run/riffle/pool geometry, bank full cross-sectional geometry, stream sinuosity a substrate map of the stream bottom, surveys of channel geomorphologic units	Stream physical habitat data is collected at six macroinvertebrate monitoring sites by NPS. Data include channel width, depth, substrate composition, and canopy cover. Data not yet analyzed.	Not applicable	Stream habitat is evaluated with the rapid bioassessement program (Plafkin and others, 1989).			USGS has drainage area and bankfull cross-sectional geometry data just upstream from park.

Lake morphometry	Mandatory: Surface area, maximum and mean depth, drainage area, lake type and origin, bathymetry, and elevation Optional: Flushing rate	Surface area, maximum and mean depth, lake type and flushing rates for many of Acadia's lakes including the five largest lakes from the 1982 resource management plan. Lake surface areas included in 2000 Water Resources Management Plan.	Not applicable	There is some monitoring of Cat Swamp Pond due to concern over dam integrity.	A bathymetric study of the impounded part of Fall-Kill Creek was conducted by Pandullo-Quirk Associates (1979).	Pond and wetland bathymetry mapped (Cronan and Associates, 1981) and Bureau of Reclamation survey of dams	Not applicable
Water quantity	Optional: Streamflow, spring seep volume ,and inventory, lake water levels, groundwater levels, groundwater inputs	Two USGS continuous-record, streamflow gaging-stations in park: (USGS stations 01022835 and 01022860). Period of record is 1999 to 2004 USGS monitors water levels and water quality at four ground-water wells on Mount Desert Island. (USGS well numbers 441516068194101, 441650068210801, 442238068154101, and 442450068175201). Three of these wells are within park boundaries. Period of record is 2003 to 2004.		Two USGS stage-gages in park (USGS station 01378775 and USGS station 01378778). Period of record is 2003 to 2004. There are several groundwater wells installed in the park- not currently in operation.		Incidental discharge measurements taken concurrently with water quality measurements by NPS. Locations of wells and seeps shown in 1992 report USGS WRIR 92-4013.	USGS continuous-record, streamflow gaging-stations on the Saugus River (USGS station 01102345) just upstream from the park. Two freshwater springs in park have been mapped and discharge measured.
Water chemistry	Mandatory: Water temperature, specific conductance, pH, dissolved oxygen, percent dissolved oxygen saturation, color and turbidity Optional: Anions, cations DOC, alkalinity, ANC, iron, aluminum	Lake monitoring by NPS in cooperation with the Maine Department of Environmental Protection in selected lakes on Mount Desert Island to monitor change due to eutrophication and atmospheric deposition. Monitoring started in the late 1970s includes secchi disk water-column transparency and surface temperature. The program continues today, with monitoring expanded to include the following: pH, Acid neutralizing capacity, Specific conductance, True color, Dissolved organic carbon, Dissolved inorganic carbon, Major ions,	The Massachusetts Water Resources Authority has monitored wastewater and effluent components, nutrients, and water chemistry (1992-2004). Parameters (not all collected at all stations) include surface and bottom water temperature, dissolved oxygen, salinity, secchi depth,	NPS monitors the following parameters on 11 sites since 1982: temperature, pH, conductivity, and salinity; and concentrations of dissolved oxygen, chloride, total dissolved solids, and fecal coliform on a monthly basis at 11 stations. Occasional samples for fecal coliforms and fecal	The park initiated a water-quality monitoring program in 1994. Temperature, pH, dissolved oxygen, salinity, and conductivity are being collected at all three units on a monthly basis. Data on additional parameters, including concentrations of chloride, phosphate, and nitrate, and	Water-quality parameters are measured at six permanent monitoring stations: water temperature, water depth, dissolved oxygen, conductivity, pH, and turbidity. NH_4 - ammonia, NO_3 – nitrate and phosphorus (PO_4 - orthophosphate) were measured in	Water- quality parameters collected monthly by the Saugus River Watershed Council include pH, dissolved oxygen, temperature, and bacteria – fecal coliform (1998-2000) and e. coli (2001-2002) Water temperature and specific conductance determined at USGS gage

		Aluminum (total dissolved), Total phosphorus, Total nitrogen, Chlorophyll a, Lake stage, Dissolved oxygen/temperature profile. Stream Monitoring: Stream temperature, pH, dissolved oxygen, specific conductance, color, and flow rate measured since 1997 on Duck Brook, Stanley Brook, Canon Brook, and Hunters Brook, and since 1998 on Lurvey Spring Brook and Heath Brook (Breen and others, 2001).	total suspended solids, and pH.	streptococcus may be taken and forwarded to an independent laboratory for evaluation. Sites are monitored once a week during the summer and once a month the rest of the year.	measurements of turbidity, and alkalinity, are being collected quarterly. Starting in 1998, this work has been contracted to a private laboratory.	previous years This program will resume in 2003.	
Fish community composition in streams	<u>Mandatory:</u> Species composition and relative abundance		Not applicable	Fish community composition data available from surveys by US Fish and Wildlife Service for Great Swamp Refuge downstream of the park		Fish species list for park made in 1986	
Zooplankton community composition in lakes	<u>Mandatory:</u> Species composition and relative abundance		Not applicable				Not applicable
Trophic status	<u>Mandatory:</u> Algal biomass, measures of water clarity such as secchi disk, and total and dissolved phosphorus <u>Optional:</u> Macrophyte distribution,(diel oxygen curve and, periphyton in streams), dissolved oxygen profiles	See water chemistry, lake monitoring	Massachusetts Water Resources Authority monitors nutrients, phytoplankton composition, and productivity. Parameters are photosynthetically active radiation, transmissivity, particulate nitrogen, total dissolved nitrogen,	Dissolved phosphorus is monitored		Dissolved phosphorus is monitored	

			nitrate/nitrite, ammonium, total dissolved phosphorus, orthophosphate, particulate organic carbon, Chlorophyll *a,* Phaeophytin			
Macroinvertebrate community composition in streams	Mandatory: Taxa richness and relative abundance	Macroinvertebrates are monitored in six streams following Maine DEP protocols (Davies and Tsomides, 1997). It has been well documented, reviewed, and provides data and analyses comparable to other streams in the state. Protocols are comparable with USEPA and the USGS National Water Quality Assessment Program protocols. The resultant data are analyzed using accepted biological and taxa composition indices.	Massachusetts Water Resources Authority monitors benthic communities.	New Jersey DEP has recently initiated a Level II Rapid Bioassessment Program (Plafkin and others, 1989) throughout New Jersey including several sites along the Upper Passaic River, Indian Grave Brook, and Primrose Brook in park. New Jersey DEP conducts macroinvertebrate sampling on the West Branch of Primrose Brook.	Two macroinvertebrate studies have been conducted in the park by the Department of Environmental Conservation in Albany, New York.	The Izaak Walton League of America's Stream Quality Survey (SQS) was performed at 4 stations in the park to quantitatively evaluate the distribution and diversity of the benthic macroinvertebrates in park streams.
Landcover/land use inventories	Mandatory: landcover/ecological system map Optional: Patch size distribution, patch connectivity, patch fragmentation, % impervious surface in buffer or watershed, canopy shading, buffer vegetation and width					
	Optional: Wet deposition, dry deposition, inorganic toxics, mercury	Park Research and Intensive Monitoring of Ecosystems (PRIMENet)- cooperative program between the USEPA and the NPS. Includes mercury and nitrogen sampling in Hadlock and Cadillac				

Atmospheric deposition		Brooks from 1998 to 2000 and air-quality monitoring of ozone, wet and dry deposition, visibility, meteorology, and UV-B monitoring. NADP sites in park include collection of wet precipitation chemistry, ozone, particulates, sulfer dioxide and mercury wet deposition. University of Maine collects fog chemistry data					
Contamination	Optional: Air toxic concentrations, MTBE, chloroforms, trichloroethylene, contaminant spills, toxic boat point, sediment contaminants, metals, bioaccumulation in indicator species	See atmospheric deposition	Massachusetts Water Resources Authority monitors toxic contaminants, pathogens, and fish and shellfish pathology.				The wetland is contaminated with polyaromatic hydrocarbons and arsenic. The slag pile has arsenic levels above the Imminent Hazard threshold, (Goff-Chem, 1996). The USGS & Massachusetts DEP, are sampling sediments in the Saugus River for heavy metals. One site is just downstream from SAIR.
Invasive exotic species	Mandatory: Presence/ absence Optional: Abundance	Multiple level surveys conducted for aquatic invasive species					Proposed restoration of historic site includes removal of invasive plants.
Septic systems/ Wastewater Discharge	Mandatory: the number of septic systems Optional:	An estimate of number of houses in rural Bar Harbor was made from 1998 digital orthophotographs and field checks in 2001 (Glenn	Massachusetts Water Resources Authority	See water quality		Fecal coliform levels were assessed three times in 2002 at four	

	Nearby permits Waste water discharges	Guntenspergen, USGS, written commun., 2001). Bar Harbor Water Company tracks municipal water use	monitors wastewater and effluent components and sewage indicator bacteria, including fecal coliform bacteria and *Enterococcus spp.*	stations

Fish community composition

None of the parks are monitoring fish community composition in streams as part of their environmental monitoring programs.

Zooplankton community composition in lakes

None of the parks are monitoring zooplankton community composition in streams as part of their environmental monitor programs

Water quality – trophic status

Nutrient chemistry data and water clarity are collected as part of water chemistry monitoring at ACAD, ROVA, and SAGA. These programs are very close to the mandatory measures for this vital sign.

Macroinvertebrate community composition in streams

All the parks except SAIR have some form of invertebrate community composition monitoring for streams. The protocols vary among the parks so there is a lack of consistency. Modification of the existing protocols to a common methodology will provide consistency for the mandatory measures.

Land use/land cover inventory

None of the parks currently have a land-use/land-cover program, but these data should be available for all the parks as state or national GIS layers.

Atmospheric deposition

Only ACAD has an atmospheric deposition component in the current program as part of National Networks such as NADP and PRIMENet.

Contamination inventory

As part of the atmospheric deposition research at ACAD, mercury and nitrogen are monitored. States provide consumption advisories for fish, but none of the parks has an active contaminants sampling program. SAIR has had sediment sampling for contaminants associated with several research projects.

Invasive exotic species

All the parks have lists of potential invaders, but monitoring is not performed on a standardized schedule.

Septic systems/wastewater discharge

This information is generally tracked by municipalities where available. In some cases it must be estimated from water use.

Protocols, Quality control, and Data Storage at NETN Parks

Each of the parks with a water quality monitoring program has components of the program that correspond to one or more vital signs; however the design of each of the programs however differs due to the objectives associated with it. Documented protocols, quality assurance/quality control, and data storage of the current monitoring programs are presented where available (table 4) in order to understand some of these differences.

Most of the monitoring programs do not have sufficiently documented protocols, quality-assurance/quality-control procedures, or data storage. Although each park has limited internal documents that provide some of this information, few published reports are available. For the data at these parks to be incorporated into the vital-signs programs and analyses, protocols will need to be standardized and documented, quality-assurance/quality-control procedures will need to be adopted and(or) documented, and data-storage practices will need to be updated. The exception is at Acadia where many of these protocols and documentation are already in place. The environmental monitoring and research program at Acadia has written protocols, written quality control specifications, a database, and an annual reports program to publish the data and analyses. As such, very little modification to the current Acadia aquatic environmental monitoring program will be required to include all the necessary vital signs.

Table 4. Standardized protocols, quality control, and data storage at the five parks with current environmental monitoring programs.

Park	Protocols	Quality Assurance/Quality Control Procedures	Data Storage
ACAD	Gawley, 1996, Acadia National Park lake monitoring: field and laboratory methods.: Acadia National Park Natural Resources Report 96-01 Kahl, and Manski, 1997, Developing long-term monitoring protocols for freshwater resources at Acadia National Park: Interim report from a workshop, January 9-10, 1997.	Gawley, W. G. 1996, Acadia National Park lake monitoring: field and laboratory methods: Acadia National Park Natural Resources Report 96-01	Internal database, Annual report series, Year end reports for lake, water, and macroinvertebrates.
BOHA			
MORR	J. Runde, 2004, Draft Report: Synthesis, analysis, and interpretation of water resources at Morristown National Historical Park Technical Report NPS/NRWRD/NRTR-xx/xx Morristown National Historical Park Standard Operating Procedure SOP Number: 601 Subject: Water Quality Testing Effective Date: October 1992 Revision Dates: April 2001	J. Runde, 2004, Draft Report: Synthesis, analysis, and interpretation of water resources at Morristown National Historical Park Technical Report NPS/NRWRD/NRTR-xx/xx Morristown National Historical Park Standard Operating Procedure SOP Number: 601 Subject: Water Quality Testing Effective Date: October 1992 Revision Dates: April 2001	Results of water quality inventory studies in the park have been reported by Mele and Mele (1983), and Trama and Galloway (1988). Storet Excel spreadsheet
ROVA			
SAGA	Zubricki, B., 1995, Water resources monitoring plan, Saint-Gaudens National Historical Site Izaak Walton League of America, 1994, Save our streams, volunteer trainers handbook.	Instrumentation calibrated and checked for accuracy	Annual interpretive reports Water quality data in Storet
SAIR			Data collected by Saugus River Watershed Council Hard copy only

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